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Why science and innovation policy needs Science and Technology Studies?

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Abstract
In the 50 years since the first specialist research centres were established to study science and innovation policy and practice, differing orientations towards modernity and to external academic and non-academic audiences have encouraged an institutional divergence between two fields today often described as Science and Technology Studies (STS) and Innovation Studies (IS). This paper explores the reasons for and consequence of this divergence in this "research field of shared interest" (Martin et al. 2012: 1182). IS, in its efforts to generate a robust evidence base from which they could draw generalisable policy lessons for promoting innovation, has adopted positivistic epistemologies and pursued large-scale and often quantitative research methods. STS, in its concern to critically interrogate the modernist project, has highlighted the diversity of voices and values of those involved in and affected by technoscientific change. This has favoured the qualitative (e.g. ethnographic and historical) methods of interpretivist research.

This paper explores how these differing political commitments and concepts of intellectual mission have shaped two key frameworks proposed respectively by IS and STS for policy intervention. We examine what is arguably the core framework of IS scholars: the theory of National Systems of Innovation and the recent espousal by STS scholars of Responsible Research and Innovation. We identify opportunities for "cross-breeding" (Velasco 2015) and productive engagement, between these two traditions. In particular IS work on science and innovation policy could benefit from revisiting its roots in historical and contextual explanation of the factors shaping innovation processes (Delvenne & Thoreau 2012). Advances here have contributed to the recent renewal of the IS research agenda (Martin 2016). However no simple (re)convergence is likely between IS and STS given their contrasting epistemic stances.

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Biography
Robin Williams is Professor of Social Research on Technology and Director of Institute for the Study of Science Technology and Innovation (ISSTI) in the School of Social and Political Science at the University of Edinburgh. He led Edinburgh's successful bid under the ESRC Programme on Information and Communication Technologies (1987-95) which formed the

basis for an interdisciplinary programme of research into 'the social shaping of technology' and culminated in the establishment of ISSTI, which brings together researchers across the University of Edinburgh in Science, Technology and Innovation Studies. His personal research trajectory focuses on the design, implementation, use and outcomes of information and communication technologies.

Keywords

Science and Technology Studies, Innovation Studies, National Systems of Innovation, Responsible Research and Innovation, Epistemic stance

Introduction

The 50th anniversary of the formation of the first specialist research centres in the field has stimulated discussion of past achievements and the future of the broad domain of Science, Technology and Innovation Studies. Opening up science and engineering – previously portrayed as the exclusive domain of technical specialists - for social scientific enquiry inspired a wide range of analytical perspectives (Williams & Edge 1996). These diverse currents seem to have largely coalesced around two poles, labelled Innovation Studies (IS) and Science and Technology Studies (STS) (Martin 2012, Martin, Nightingale & Yegros-Yegros 2012).

How has “a research field of shared interest” (Martin et al. 2012: 1182), with strongly overlapping concerns and empirical coverage, coalesced around diverging epistemic stances? Can lessons be drawn about the dilemmas of analysing and intervening in Science and Innovation policy and about the scope for more productive interactions between IS and STS?

A number of recent literature reviews have appeared that redress the surprising dearth of a sociology of STS (Siler 2012; Jasanoff 2010; Martin et al. 2012) and IS knowledge (Sharif 2006; Fagerberg & Verspagen, 2009; Godin 2009; Morlacchi & Martin 2009; Fagerberg et al. 2012; Martin 2012; Fagerberg et al. 2013; Martin in this volume). Siler (2012) analyses STS as a Scientific and Intellectual Movement to explore “social processes both endogenous and exogenous to the intellectual field” (Frickel & Gross 2005: 222) that shape how scholars frame their work to outsiders and insiders. This echoes Knorr-Cetina’s (1999) analysis of the emergence of distinct ‘epistemic cultures’ and machineries for the production, validation and consumption of knowledge and draws our attention to how a specialist community seeks to establish its relevance to target audiences (Turner 2001).

This chapter explores the common origins of IS and STS and briefly reviews how these fields have evolved. We examine the differing epistemological choices made by IS and STS and how they relate to diverging conceptions of their core mission and orientation to external audiences. These are explored through reviews of two areas where IS and STS have, respectively, have projected particular claims to external relevance – National Systems of Innovation (NSI) theory and Responsible Research and Innovation (RRI).

The Origins of STS and IS

When the fields of STS and IS first emerged there were no existing experts. Though some moved in from cognate Humanities and Social Science (HSS) disciplines such as economics, history, management, philosophy, and sociology, a significant segment, and perhaps the majority of the first generation of scholars, had backgrounds in science and engineering. Many early STS researchers made this transition through their involvement in the Radical Science Movement and 'science shops' in northern Europe (Rip forthcoming).

These fields were differently constituted in different nations and universities, populated by various combinations of these contributory currents (Cronberg and Sørensen 1995). With sustained movement of staff between different centres and traditions (Williams & Edge 1995), most scholars in the field work in hybrid institutional environments (Hilgartner 2004) that included a variety of intellectual currents including STS, IS and other traditions (for example technology management). Notwithstanding weak boundaries around and within this embryonic domain (which was markedly heterogeneous in terms of theory and methodology), we note the growing influence of a few large research centres, journals and conference series that specialised in one or other tradition. Over time, the traditions have drawn apart to the extent that a recent citation analysis (Bhupatiraju et al. 2012) suggested that these fields, "although they share research topics and themes, have developed largely on their own and in relative isolation from one another." Though the historical accuracy of this statement is questionable, it is deeply revealing about the mutual orientation and awareness of academic communities.

A key feature in this divergence has been the turn of STS towards constructivist viewpoints (Siler 2012), whilst IS pursued a positivist epistemology (Martin 2012). This is associated with different preoccupations and conceptions of the intellectual mission of the specialism and especially how it related to external audiences. These differing intellectual and social commitments often remain tacit, so it may be useful to briefly characterise them.

Emergence and Evolution of IS

The IS community formed around the elaboration of NSI theory, which was closely associated with the programmatic development of evolutionary economics. The latter advanced a critique of mainstream (e.g. neo-classical) economics - already deeply entrenched in industrial policymaking – with which they competed for cognitive authority (Martin 2016). In an era in which the promotion of innovation has become a key policy concern, the NSI concept has been rather successful in creating a receptive policy audience (Sharif 2006, Martin 2012). Other cognate traditions, particularly in technology management, were drawn into this nexus (Fagerberg et al. 2012).

This desire to secure access to external innovation policy and technology management communities has, arguably, encouraged a particular conception of how IS knowledge is produced and may be applied. A concern to provide a robust evidence base that can inform policy choices seems to have favoured certain kinds of positivistic approaches to knowledge production. IS research typically emphasises large scale and quantitative treatments (perhaps using citation analysis, patent analysis or structured surveys). The emphasis is upon creating generalizable knowledge – e.g. using statistical analysis to test models and identify success factors - which could be extrapolated to other settings. Scholars pursued an epistemic model akin to natural science to achieve the cumulative development of knowledge amongst a community of scholars who had "mastered a common body of literature" and are thus "well placed to build upon this efficiently" (Martin in this volume) through the incremental elaboration of methodologies and explanatory schema.

Another feature of the orientation of IS towards innovation communities in industry and government has been a more or less explicit pro-innovation bias (Viotti 2002) evident in widely adopted terminologies, e.g. of 'barriers to innovation' and the 'critical success factors' that may help overcome these. NSI arose from a concern to explain sustained differences between national economies in aggregate rates of innovation (Freeman 1995). It thereby focused on the overall rate of innovation, rather than particular pathways/directions of innovation.

Emergence and evolution of STS

STS has diverse intellectual roots; each brought rather different intellectual legacies. It inherited traditions from the 1960s Radical Science Movement which drew attention to the unintended and undesired consequences of science, technology and innovation coupled with growing awareness of the potential risks of new technologies and biomedical innovations. These raised questions about the actors and contextual factors shaping technological development pathways (MacKenzie & Wajcman 1985) and opening up technological and scientific controversies (Engelhardt & Caplan 1987). These concerns were framed within a wider questioning of modernity including a critical interrogation of the authority claimed by technical experts. This underpinned an enduring concern to critically interrogate the privileged role of technical and other specialists in policymaking (Jasanoff 1990) and give voice to laypersons and to other potentially excluded actors.

From the outset, STS scholarship engaged with the content of science and technology (S&T) and the direction as well as the rate of change. In reaction against prevalent 'heroic' portrayals of the progress of S&T as self-evident processes of elimination of error and improvement of artefacts, Bloor's (1976) symmetry principle in science, extended to technology by Pinch and Bijker (1984), instead explores how success and failure (and criteria for evaluating success) are constructed. In reaction against modernist claims about the universal applicability of scientific facts and artefacts, detailed ethnographic case studies of sites of S&T production, exemplified by Latour & Woolgar's (1979) classic *Laboratory Life,* stressed the local character of S&T achievements. STS research increasingly focused on processual accounts of technoscientific developments in particular settings. This (variously described) interpretivist or localist turn encouraged explanations of techno-scientific change in which outcomes were seen to be highly contingent on interactions between local actors. The consequent emphasis on contingency led STS scholars to urge extreme caution about extrapolating from particular cases. This posed particular problems about how to derive advice for policy and practice (Sørensen & Williams 2002).

These differences in trajectory between IS and STS lead to more or less contrasting analyses of innovation processes. For example foundational IS research drew attention to 'coupling' between technology suppliers and (industrial) users (Freeman 1974) and how the knowledge flows that this enabled between them underpinned a 'learning economy' (Lundvall 1988, Lundvall & Johnson 1994). Their work however shared with economics a concern to explain differences in aggregate outcomes. STS writers had similar interests but their work instead pushed down to explore in finer detail the contents and specific mechanisms of knowledge exchanged (Faulkner et al 1995).

Similarly, though IS writers like Freeman (1995) were critical of 'linear models' of innovation propelled by advances in S&T, it fell to STS analysts to empirically demonstrate how innovation is not confined to the R&D laboratory but continues as technologies are implemented (Fleck 1988) and appropriated (Silverstone & Hirsch 1992) as a result not just of formal R&D but also dispersed trial and error processes of Social Learning (Sørensen 1996).

STS studies of innovation drew attention to the fragile and unpredictable outcomes of 'innovation journeys' (Latour 1996, Van de Ven 1999). STS analysts highlighted the complex, intertwined and indeed inseparable interplay between social and technical factors in science and innovation (Hughes 1986, Law 1987). This sociotechnical approach highlighted the specificity of particular areas of innovation rooted variously in their institutional (e.g. regulation) and material contexts (Tait & Williams 1999). IS analysis has begun to address these specificities through paying attention to particular *Sectoral and technological systems of innovation* (Malerba 2002, Bergek et al. 2015).

STS scholars have from the outset been interested in the control of technology as much as its promotion. Their enduring interest in the potential risks (to health and the environment as well as 'social impacts' and ethical values) that may result from sociotechnical change has informed a concern to analyse the content of innovation and open up choices and controversies over pathways of techno-scientific development.

The difficulties in controlling the development of technology and especially of mitigating its effects after it has become widely entrenched (Collingridge 1980) motivated attempts to anticipate and intervene proactively in techno-scientific development such as the idea of Constructive Technology Assessment (CTA) (Rip et al. 1995; Schot & Rip 1996). CTA seeks to identify and intervene around branch points in technology development that may introduce risk and other undesired outcomes.

The peri-millennial controversy over the health and environmental implications of genetic engineering in agriculture heralded a period of escalating public concern about 'New and Emerging Science and Technology' (NEST). Policymakers' desire to understand and manage public attitudes motivated widespread attempts to promote 'public engagement' particularly around potentially controversial NEST fields such as nanotechnology and genetic engineering. STS scholars have become involved in surveying public attitudes, studying how public engagement exercises have been conducted and have also become directly engaged in running public engagement initiatives (Irwin et al. 2013). Concern that public engagement should not merely react to techno-scientific choices already made within the laboratory motivated proposals to move engagement 'upstream' (Wilsdon & Willis 2004). The recent proliferation of large-scale public-sector funded research programmes across many fields has brought substantial funding opportunities for STS researchers, particularly in Europe, most recently in relation to RRI initiatives.

Current developments in STS

The field of STS remains highly dynamic in terms of conceptual innovation, its objects of enquiry and ongoing debates about its relationship with and contribution to practice. Salient here are the sustained efforts of Rip and co-workers at the University of Twente to develop integrated models that bridge between STS studies of innovation dynamics and IS and related evolutionary economic insights into systemic developments and the influence of policy interventions. We note the progressive extension of the CTA framework, and its application to the challenges of transition to environmentally 'cleaner' systems of production and consumption. Proposals about the need to protect immature prospective new technologies through 'strategic niche management' fed into the development of the Multi-Level Perspective (Kemp et al. 1998; Geels 2004) which explicitly borrows from Nelson and Winter's (1977) evolutionary economic analysis of technology regimes and broader selection environment.

The intellectual agenda for STS has been continually renewed and revitalised by its engagement with new problematics from HSS domains which in turn have provoked fundamental debates about the character of sociomaterial phenomena and the tools by which they may be investigated. For example, feminist writing has not only contributed substantively to the STS intellectual agenda; feminist standpoint theory (Haraway 1988, Harding 2004) made a significant epistemological contribution to STS thinking – providing tools for acknowledging the partial and locally situated character of knowledge production – a move which sought to avoid the dichotomy between simplistic positivist and relativist positions and between descriptive and normative orientations.

Some IS commentators have made a contrasting interpretation of these sustained debates between competing traditions in STS as a shortcoming rather than a strength. Martin et al, (2012:1195) see these as "rather 'tribal'" divisions, and point to the failure of STS "to construct a common conceptual and analytical framework or 'paradigm'." There have been concerns within the STS community about its failure to systematise its conceptual frameworks (Russell & Williams 2002, Jasanoff 2010). STS scholars however have tended to see these sustained debates as an indicator of the continued vigour of the field, constantly opening up new problematics and conceptual schema.

The rapid and sustained growth of the STS scholarly community can be linked to the increasing salience of science and innovation in society. The growing scale and pace of research continually opens up new landscapes for enquiry (or "new turf" Siler 2012). STS scholars are well-placed to address these developments, and, given policy concerns about effective exploitation and public responses to large-scale public funded NEST research programmes, have been well positioned to secure research funding and attentive policy and wider audiences. Here STS scholars were able to take advantage of a body of relatively simple generic analytical tools that could readily be applied to a range of contexts (Siler 2012). Those outside the field also found purchase in STS concepts – and STS has grown in part by attracting HSS scholars from cognate fields such as sociology, history, business and cultural studies.

STS scholars have also embarked upon 'deeper' forms of interdisciplinary engagement with S&T practitioners. One of the founding missions for STS was to 'open the black box' of science and engineering in order to explore the operation of 'social' factors within what had previously been portrayed as 'technical' realms. STS from the outset thus inherited a deeply entrenched aversion to the establishment of disciplinary structures and boundaries between fields (Siler 2012: 1404; Sørensen 2012). Many of its practitioners have, accordingly, been keen to transgress disciplinary boundaries and produce transdisciplinary accounts that could more effectively capture the multidimensional complexity of sociomaterial processes, rather than fragment explanation through particular disciplinary lenses.

Here STS work resonated with (and contributed to) a wider critique of traditional disciplinary specialisation. This suggested that complex and multi-dimensional real world problems needed to be addressed by combining different types of knowledge (Gibbons et al. 1994). Science and innovation policy increasingly sought to promote collaboration between scientists and engineers and HSS scholars which was seen as potentially contributing to more effective and harmonious exploitation of S&T research and generating more comprehensive solutions to the grand challenges facing society. The consequent inclusion within large public research programmes of initiatives to address their ethical, legal and social implications (ELSI) opened up a space into which STS scholars and other HSS specialists (e.g. from Law, Philosophy) were attracted. These developments created opportunities for STS specialists to become directly involved with science and engineering endeavours: to "press into the domains where the designers of the future operate" (Jasanoff 2016: 235). They offered opportunities to secure research funding and access to key sites of techno-scientific development. They also threw up dilemmas for STS scholars about their role and responsibility.

Against this background of extensive growth, concerns have been expressed that "the intellectual strength of STS is not matched by a corresponding institutional robustness" (Hilgartner 2004: 201). Leading STS scholars warned of the dangers of eclecticism (Jasanoff 2016). Hilgartner (2004) suggested that STS faced a choice between presenting itself as a discipline or an interdiscipline. Though allowing free movement into the field created opportunities for growth, there might be costs in terms of loss of "intellectual coherence", holding back development of the field, and allowing "too many competing interests…. to claim the territory" (Jasanoff 2016:234). They warned that the "interdisciplinary model also entails some degree of subordination of STS to traditional disciplines" (Siler 2012:1397). To enhance the autonomy and status of STS within the academy they proposed that STS should exploit the kinds of institutionalisation strategy it had observed in the disciplinary projects of other epistemic communities: establishing a consensus about core literatures, figures and approaches and limiting access to those who had completed a PhD in the field (Jasanoff 2010, Siler 2012). STS should establish itself as "a field of its own" (Jasanoff 2010: 191) conceived as "an independent disciplinary formation situated among other disciplines".

It may not be a coincidence that these calls mainly originated in the USA where specialist STS centres are largely concentrated in leading research universities (Siler 2012). STS departments seeking to strengthen their position in such settings have, understandably, emphasised the scholarly route. In contrast, across Europe, the dramatic and sustained growth in the size of the STS community has been achieved through not only through growth in the number and size of leading STS centres, also through the attraction to STS of individuals and clusters of scholars in other disciplinary locations and, crucially, the sustained presence of hybrid centres involving a mix of STS, IS and other approaches. Sørensen (2012: 58) draws attention to the rhizome-like character of the STS field "spreading through interaction with, but also in-between, a large number of disciplinary and interdisciplinary fields". This has to be seen against a context of strong support for interdisciplinary research by various European national and international research funding agencies. The differences in emphasis in part reflect differences in institutional constraints and opportunities. STS scholars, operating in domains already occupied by entrenched older disciplines, have been forced to become expert in securing their position within their particular institutional landscapes, weaving protected positions in the interstices between more established blocks (Jasanoff, 2016; Williams 2016).

Despite differences of emphasis, few STS scholars would dissent from Jasanoff's call for a "more disciplined approach to doing STS" (Sørensen 2012: 59), involving "critical stock-taking, meaningful theorizing and methodological innovation" (Jasanoff 2010: 204) a position that Sørensen (2012:59) has characterised as 'disciplined interdisciplinarity'.

NSI and STS Epistemic System – tensions between research and intervention

NSI epistemic system

Evolutionary economists criticised the failure of mainstream (neoclassical) economics to incorporate institutions into their theories and models (Godin 2009). The NSI perspective emerged from historical and institutional analyses of how innovation processes were conditioned by their *particular settings*. Freeman (1995) explained the differential performance of particular NSIs in Japan, USA, Europe and the then Soviet Union in terms of their historical, and institutional specificities (including for example "mutual trust and personal relationships" p.21]). Another foundational contributor, Lundvall, (1985: 3) highlights how his analysis of the learning economy was rooted in studies of "how users interact with producers in specific parts of the economy and under specific historical circumstances."

However the early focus on specific historical and institutional settings gradually gave way to a concern to characterise the systemic features underpinning the differential aggregate performance of nations (Sharif 2006). Godin (2009) highlights the influence of the Organisation for Economic Cooperation and Development (OECD 1992) in the turn to a system theory perspective. Sharif (2006: 751) suggests that Freeman's (1987) analysis was seen as "too challenging" by the OECD because of its attention to factors outside the neo-classical economic framework. The NSI framework seems to have become simplified as it was converted into a tool for policy intervention.

There have been debates amongst NSI writers about the coherence of the framework and whether it should be seen as a heuristic rather than a theory. Edquist (1997), the third core theorist of NSI, highlighted inconsistencies in definition of its core concepts (e.g. institution). Despite this, the NSI scholarly community has exhibited sustained and rapid growth. NSI theory has gradually become stabilised and has in turn spawned a large array of studies that have progressively elaborated the framework (Martin 2012:1237). A burgeoning literature explores in detail the operation of various elements of NSIs across a growing range of regions and sectors – to the point that leading exponents (Martin in this volume) have been moved to warn of the danger that specialisation and risk aversion might encourage researchers to focus upon "an ever smaller part of the process or phenomenon under study", potentially yielding trivial findings.

The growth of the NSI research community went hand in hand with its establishment of a receptive community of policymakers attached to science and innovation (Lundvall 2007). The OECD helped facilitate the dissemination of the NSI framework and supported its implementation inter-alia by establishing indicators (Godin 2009). NSI came to be proposed as solution, beyond the OECD 'charmed circle' of developed countries, for more or less rapidly developing economies, supported for example by UNESCO and other international bodies (Delvenne & Thoreau 2012).

The close relationships between NSI research and policy communities - which drove its growth - also created tensions and dilemmas (Sharif 2006). Miettinen (2002) suggests that researchers and policy makers have become unhealthily close, to the point that they have become dependent upon – indeed captured by – the other. This is despite concerns about the applicability of the NSI framework and deeper uncertainties about whether attempts to replicate features seen as driving success in one nation, region or sector will succeed elsewhere (Tait & Williams 1999; Brown et al. 2016).

The diffusion of concepts inevitably also involves their transformation (Sørensen 1996). Lundvall (2007) complains about the 'distortion' of the NSI concept as originally conceived by the emergence of a "focus on science-based innovation and on the formal technological infrastructure and in policies aiming almost exclusively at stimulating R&D efforts in high-technology sectors" (Lundvall 2007:1) and the neglect of practice-based *learning-by-doing* amongst industrial players and of tacit c.f. formal knowledge flows. Delvenne and Thoreau (2012) criticise the espousal of a 'reductionist' version of NSI as a generic prescription across a range of (developing as well as developed) nations, that leaves little scope to address the historically and geographically located complexities of particular nations and regions. They call for NSI to take on board the "situated socio-political contexts and local realities, while taking global developments into account" (Delvenne & Thoreau 2012: 216) – a move that, paradoxically, would take it back to its roots!

STS epistemic system – the case of RRI

Many STS researchers are keen to engage with issues of policy and practice. However this endeavour has provoked considerable heart-searching and there is no simple consensus within the STS community about its role in relation to techno-scientific development, its audiences and the kind of relationship it seeks with them.

Early STS insights into the unanticipated outcomes of S&T and the difficulties of controlling these retrospectively stimulated various proposals for anticipatory governance to mitigate not just health and environmental risk of NEST but also ELSI. These typically shared a concern 1) to involve a wider range of publics, especially lay publics, in discussing the development and implications of NEST and to enhance engagement between innovation communities, STS scholars and a wider range of stakeholders, and 2) to pursue ways to integrate concerns about potential ELSI into choices made in the course of techno-scientific research and development rather than address them as an afterthought.

These concerns have recently become encapsulated in proposals for RRI, defined as "*a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)*" (Von Schomberg, 2011). The RRI concept was rapidly adopted by research funders from Europe and beyond.

The promotion of RRI within public research programmes has paradoxically created dilemmas and debates amongst STS scholars, whose deconstructive instincts lead them to explore the contradictions of a concept that other STS colleagues played a key role in fostering! Some STS scholars became involved in RRI initiatives which offered privileged access to sites of techno-scientific research, new avenues of engagement and new sources of research funding. Many of these strenuously sought to avoid being cast into particular roles – and in particular against being portrayed as the people that scientists and engineers bring in to address tricky issues of risk governance and public acceptance (Balmer et al. 2015). STS scholars also began to study how RRI policies had been implemented. There was concern that RRI initiatives might become co-opted by the agendas of innovation communities – for example that engagement exercises might be recast as a mode of managing the acceptance of NEST (Williams 2006) – or be ineffective. The latter might occur if RRI objectives were implemented in a mechanistic manner – for example where RRI had been reduced within public research governance procedures of the European Union to a set of specific codifiable (and readily monitored) properties such as commitments to maintain scientific integrity; to follow research ethics procedures, to allow open access to research findings and data; and, to pursue gender equality. In reaction, Stilgoe et al. (2013) mapped out a broad and open agenda for RRI geared towards anticipation, reflexivity, inclusion and responsiveness. In NEST fields, such as nanotechnology and synthetic biology, STS scholars have worked to create and foreground more diverse conceptions of their role and relationship with the scientists and engineers involved (Balmer et al. 2015), working with specialists and other groups such as artists to open a space for thinking about possible techno-scientific futures (Frow & Calvert, 2013).

We see that STS ends up with a complex and rather heterogeneous array of orientations toward RRI – becoming involved as critical practitioner as well as critical reviewer. The tension between the contradictory goals of intervention and reflection are played out differently by different currents within STS.

Concluding discussion

We have considered the emergence and development of IS and STS and the dilemmas posed by their attempts to engage with policy and practice. The tensions between analysis and intervention have been differently played out. We have seen how the different epistemic commitments of these fields (e.g. between positivism and interpretivism) have gone hand in hand with very different conceptions of their external audiences and how to relate to them.

Both traditions seek not merely to describe and in different ways seek to influence the world. NSI had a very clear view of its mission (the critique of mainstream economics) and strong and sustained relationships with the Innovation policy world that it helped foster. STS, despite the methodological relativism that resulted from its insistence on treating symmetrically knowledge claims and artefacts that subsequently succeeded or failed, was founded around a critical engagement with modernity. A concern to intervene around the social character and implications of science and innovation led many proponents to follow a 'normative turn' away from disinterested enquiry (Sismondo, 2007; Lynch 2014). This (re)turn has not been without anxiety. Though the oscillation between analysis and intervention has been productive, there is a sustained lack of consensus within STS about its goals and audiences. The most widely shared (albeit still largely tacit) conception of the mission and audience of STS has been to inform and thus emancipate marginalised 'lay' actors in the face of powerful techno-scientific or policy elites. In contrast its ambivalence towards S&T may create difficulties in its relationships with practitioners (McLoughlin 1999, Martin et al. 2012, 2016). Attitudes are diverse however and recent work has seen the renewal of STS ambitions and strategies to engage a wider array of stakeholders, including science and innovation communities, and explore a wider range of orientations towards technoscience (Felt et al. 2016). This can be illustrated by the cyber-feminist perspective (Haraway, 1991) which explored the liberatory potential of internet technologies for women – partly in reaction against widespread pessimistic STS accounts of its implications for personal privacy and autonomy. Today, notwithstanding a diversity of orientations, many STS practitioners are developing closer engagements with technoscience – including direct involvement in opening up science and innovation (e.g. through citizen science or participatory design initiatives). To manage their marked ambivalence about this close relationship with practice (driven by anxiety that they might as a result become 'trapped' into commitments to particular techno-scientific projects), STS scholars have become Janus-faced: coupling their engagement with intense reflection upon the process and implications of such engagement. Rip (1998) applies the image of 'The Dancer and the Dance' to capture this oscillation between moments of action and reflection. This metaphor has recently been taken up in a significant reflexive turn by IS scholars (notably Kuhlmann 2010). This move could herald a mission for STS and IS scholars to recombine around a role as conscious co-shaper of science and innovation policy and practice.

The sustained and insistent emphasis within STS on reflexivity has not been matched in IS debates. Though IS has engaged confidently with the evolving challenges for innovation communities in a changing world, there has (until recently) been little reflection on its epistemic stance. IS scholars, with stable sets of concepts and a close relationship to policy targets, have perhaps not felt as much incentive to reflect upon their own engagements to the same degree as their STS counterparts. Interestingly today we see a new generation of IS writers coming to the fore who have begun to revitalise the IS agenda (Morlacchi & Martin 2009; Martin 2016). Substantively they have begun to pose questions about the direction as well as the pace of innovation - questions that were hitherto were the concerns of STS (MacKenzie & Wajcman 1985). This change seems to have arisen most immediately as a result of addressing the challenges of global warming - where IS scholars have engaged with the transition to environmentally sustainable systems of production and consumption (Bergek et al. 2015). Similar questions have arisen where IS scholars have explored issues confronting international development (Delvenne & Thoreau 2012) where themes of pro-poor innovation and 'innovation below the radar' (Kaplinsky et al. 2008) highlight, respectively, science and innovation for and within developing countries (Kuhlmann & Ordóñez-Matamoros 2017; Arocena et al. 2017). These IS colleagues flag the role of historical and sociological approaches – and by extension the relevance of STS (Delvenne & Thoreau 2012, Morlacchi & Martin, 2009, Martin 2016).

These instances represent the most recent example of a number of periodic attempts to pursue a closer relationship between STS and IS (see Velasco 2015). Science and innovation policy offers a key area in which both the IS and STS traditions might productively combine. IS scholars have a strong substantive interest in innovation policy. However it would appear that the programmatisation of NSI theory has encouraged a normative focus on what innovation policy should look like and diverted attention away from analysing policy development and implementation (Miettinen 2002, Sharif 2006, Delvenne & Thoreau 2012). Though detailed studies have focused on the development of local innovation capacity there has been a neglect of contextual issues of power and culture.

IS has not given particular attention to science policy. The success of NSI theory may be one reason why science policy has received less systematic attention than innovation policy. The once distinct field of STP studies has been relatively weak and isolated from both mainstream IS and STS traditions. Contributions from political studies have been seen by STS scholars as unduly descriptive, veering towards an instrumental focus, and offering a high level account that overlooks the internal dynamics and contingencies of the policymaking process. Paradoxically, an almost exact obverse critique could be advanced of STS contributions in this field, which, revolving around localised ethnographies of particular laboratories, centres and communities (arguably as a by-product of the success of laboratory studies), have tended towards a bottom up focus. Predominant STS research designs are often fragmented between different fields and have offered less ethnographic access to and insight into the operation of higher policy levels.

STS has, of course, been intensely concerned with the policy framings that drive the funding and shape the growth of particular fields of science and innovation (perhaps most notably in work on the sociology of promise [Brown & Michael 2003]). However much STS enquiry is centred around ethnographic study of the work of scientists in conducting and perhaps exploiting research in particular fields. The content of policy has often been addressed through analysis of documentary sources with little direct (i.e. ethnographic) engagement with the policy development and implementation process *per se*. The bottom-up character of much STS research (often localised with particular techno-scientific domains) leaves relatively under-examined the overall structures and dynamics of national Science and Innovation policy processes, let alone the processes of competition and mimicry between national research administrations that have come to increasingly shape science and innovation policy in the three decades since Japan launched its 5th Generation Computing programme (Spinardi & Williams 2005). STS work on policy has instead been preoccupied with subjecting to critical analysis prevalent 'technocratic' conceptions of the contribution of

S&T specialists to public policy (Fischer 1990; Jasanoff 1990). They have questioned claims of specialists to privileged access to policymaking on the grounds of competence and disinterestedness and the legitimatory role of science in policymaking. The focus of critical attention (and empirical research) on the role of technical specialists in the science-policy nexus and the lack of attention to other components of the policy-process has had an unintended consequence of allowing an almost rationalistic account of that policy process to prevail. There have been important contributions from policy studies, deploying sociological concepts and methods broadly similar to and compatible with STS, to analysing the specificity of policy development and implementation processes (see for example Næsje [2002]). Insights at the interface between STS and policy studies may also help IS scholars develop more effective understandings of NSI policy development and innovation processes (Flanagan & Uyarra 2016).

This review contends that the fields of STS and IS have not been truly separate. They are, however, divided by their different intellectual missions and tacit commitments and also by the different internal and external audiences to whom they are oriented. This is one reason why, even when working in same substantive areas, there is only limited cross-citation of work from the other tradition (Bhupatiraju 2012). As a result, though there is ample opportunity for productive engagement, no simple (re)convergence between these two traditions is likely given their contrasting epistemic stances. STS in particular has been expanding its purview - finding advantage from looking out to cognate fields with complementary strengths and territories (organisation studies; information systems; energy studies). Thus some of the most dynamic intellectual developments (e.g. ongoing debates about performativity and agency) have arisen from the pathbreaking journey of STS scholars into the new sociology of markets (MacKenzie 2006; Callon 2007). IS scholars have also engaged with some of these domains. So the likely outcome would be extensive growth and the further elaboration of a rich and heterogeneous evolving web of approaches, countering tendencies towards convergence around a common core.

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